Research Article

Effect of inspiratory muscle training (IMT) on aerobic capacity, respiratory muscle strength and rate of perceived exertion in paraplegics

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Objectives: The purpose is to study the effect of inspiratory muscle training on aerobic capacity, respiratory muscle strength and rate of perceived exertion in paraplegics.
Study Design: Randomized controlled trial.
Settings: Rehabilitation department in Indian Spinal Injuries Centre, New Delhi.
Participants: A sample of 30 paraplegics (T1-T12) were randomly allocated into two groups: inspiratory muscle training (IMT) group and control group.
Interventions: The IMT group received inspiratory muscle training for 15 minutes 5 times a week for 4 weeks whereas the control group was given breathing exercises.
Outcome measures: Maximal inspiratory pressure(MIP), maximal expiratory pressure (MEP), modified Borg's scale (MBS), 12 minute wheelchair aerobic test (12MWAT), multistage fitness test (MSFT), and 6 minutes push test (6MPT).
Results: Out of 30 participants, 27 completed the study. The results show that after four weeks of IMT training, there were significant improvements in mean change scores of IMT group as compared to control group. Participants in IMT group performed better on 12MWAT ($P = 0.001$), MSFT ($P = 0.001$) and 6MPT ($P = 0.001$). Improvements in MIP scores ($P = 0.001$), MEP scores ($P = 0.001$) and MBS scores ($P = 0.004$) were also seen in IMT group.
Conclusion: Both groups showed significant improvements, however inspiratory muscle training was seen to be more effective than deep breathing exercises for improving aerobic capacity, respiratory muscle strength and rate of perceived exertion in paraplegics.

Keywords: Spinal cord injury, Inspiratory muscle training, Aerobic capacity, Respiratory muscle strength

Introduction

Respiratory dysfunction following spinal cord injury is a major cause of morbidity and mortality.[1] Lesions above C3 result in complete paralysis of respiratory muscles including diaphragm while lower lesions involve selective respiratory muscles. The extent of dysfunction depends both on level of injury and completeness of injury.[1] Impairment of muscles of respiration post spinal cord injury (SCI) results in reduced lung volumes and decreased chest wall compliance.[1] This, in turn, increases the risk of respiratory tract infections, increased oxygen cost of breathing and inspiratory muscle fatigue.[2]

The reduction in respiratory function can significantly affect exercise tolerance in SCI patients.[3] Furthermore, reduced physical capacity associated with sedentary lifestyle and physical inactivity results in breathlessness, exercise intolerance and decreased aerobic capacity.[1,3]

Aerobic capacity in SCI patients depends upon a number of factors such as level of injury, body mass index, age and activity level.[4] Studies have shown that aerobic capacity in paraplegics is lower as compared to able body persons.[5] Previous studies on able-bodied individuals have shown that training of respiratory improves their respiratory muscle function which in turn affects their aerobic capacity and fitness levels.[6–9]

Inspiratory muscle training (IMT) is a therapeutic technique which involves specific training of respiratory muscles to yield improvements in inspiratory muscle

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strength and respiratory function.[10] Previous studies have shown positive effects of IMT on exercise capacity in able-bodied individuals[1] and other neurological conditions.[11] In spinal cord injured improvements in peak exercise responses were seen in quadriplegics[12] and Paralympic athletes.[3] Despite the above evidence there is insufficient literature on the effect of IMT on exercise responses in untrained non athletic SCI population. Hence, the purpose this study was to see the effect of IMT training on aerobic capacity in non-athletic SCI population.

Methods

Participants and design

An assessor-blinded randomized controlled trail was undertaken. The distribution of sample and sample size is explained in CONSORT flowchart (Fig. 1). Participants were recruited from rehabilitation department of Indian Spinal Injuries Centre, New Delhi. Paraplegics with level of injury T1-T12, time since injury ≥ 3 months were included, 18 years of age or older, complete/incomplete injury(AIS Grading), who were able to propel a manual wheel chair independently for 5 minutes were included. Participants excluded were those on medications (e.g. Beta blockers, Ca++ channel blockers) that could affect the heart rate; with pre morbid respiratory conditions (asthma, COPD, restrictive lung diseases etc.) and current smokers.

Interventions

The participants were asked to sign a written informed consent form. For randomization of participants into two groups a computer generated random allocation schedule was created by a person other than the principal investigator. To ensure concealment, the allocation schedule was sequentially numbered and sealed in opaque envelopes. A person not associated with the study opened the numbered envelopes sequentially to reveal the participant's group allocation. The two groups were: Group 1 (IMT group) and Group 2 (control group). The study was approved by the institutional research review committee and the institutional ethical committee of Indian Spinal Injuries Centre.

Group 1: IMT group

The training was carried out in the rehabilitation department of Indian Spinal Injuries Centre under supervision.

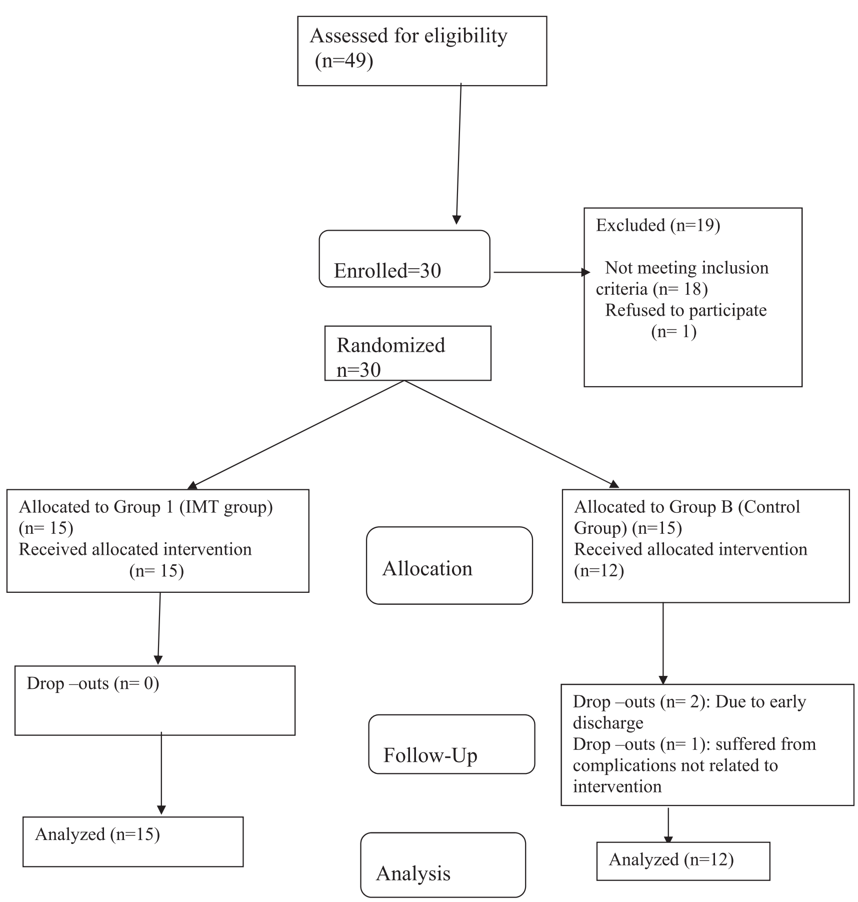

Figure 1 CONSORT diagram.

The participants sat comfortably in their wheelchair. Before starting the procedure maximum inspiratory pressure (MIP) was obtained using the capsule sensing pressure gauge manometer, as described below. For the purpose of training Philips Threshold® IMT Inspiratory Muscle Trainer was used. The mouth piece of the threshold trainer was put inside the participant's mouth and nose clip was attached to prevent any breathing through the nose. The participants were instructed to breathe in a force to overcome the resistance of a spring loaded valve and enable airflow. The resistance of the inspiratory muscle threshold trainer was adjusted at 40%[14] of the obtained MIP. The resistance was increased to the next level as the participants completed 50 breathes without any difficulty for consecutive 3 days. Participants repeated this maneuver for 15 minutes[15] with 2–3 minutes rest periods in between. Intervention was given 5 days a week for four weeks.

Group 2: Control group

The participants in the control group instructed to inspire maximally, predominantly with abdominal motion, while reducing upper ribcage motion. Respiratory control was achieved by encouraging deep, slow inspiration followed by gentle expiration with pursed lips. Tactile feedback was given with one hand of the patient on the abdomen and the other hand on the upper ribcage.[16] This cycle was repeated 60 times per session twice a day for 20 days. Intervention was given for 15 minutes, 5 days a week for 4 weeks.

Pre and post intervention data were collected for the following primary and secondary outcome measures.

Outcome measures

Primary outcome measures

12 minute wheel chair aerobic test (12 MWAT)

It is a field test which is used to measure the aerobic fitness (measured in terms of VO_2 max) of wheelchair users. The test was performed in a 25×15 meter rectangular course with a perimeter of 75.32 meters. The participants' heart rate was measured before and after the start of the test. Cones were placed at the 4 corners of the rectangle. Participants wheeled around the track for 12 minutes, and the distance covered was recorded. The participants were encouraged to push themselves as hard as possible. Scoring was done according to the distance covered by the participants in 12 minutes at maximal speed.[17] VO_2 max was calculated using the following formula:

$$VO_2\text{max (ml/kg/min)} = (29.623 \times \text{distance in meters}) - 10.916$$

Multistage fitness test (MSFT)

In this test the participants were asked to wheel around an octagonal course in a space of 15×15 meter floor space delimited by cones. The initial wheeling velocity was set at 6 km/hr, which was increased by 0.37 km/hr in one minute interval. The participants had to cover the sides of the octagonal course on this wheelchair and were supposed to be within the next turning zone at each beep. Scoring was done by calculating the number of octagonal courses completed. If the participant coursed more than 3 turning zones of the octagonal course it was counted as one complete course.[18]

Six minutes push test (6MPT)

This test is used to assess the endurance of a participant using wheelchair. The participants propelled the wheelchair as far as possible on the propulsion course which was a 30 meter loop, marked by two cones spaced 15 m apart with 2.8 m on either end to allow for turning. Two 180 turns were required to complete one 30-m loop. Distance traveled in 6 minutes was computed by multiplying the number of completed laps by 15 m and adding the distance traveled in the last lap in meters.[19]

The above tests were terminated in case of onset of angina or angina like symptoms, drop in systolic BP of >10mmHg from baseline BP; excessive rise in BP: systolic pressure >250mmHg or diastolic pressure > 115mmHg; leg cramps / claudication; or/ if participant requests to stop. In order to maintain consistency data were collected at the same time of the day.

Secondary outcome measures

MIP and maximum expiratory pressure (MEP) measurements

MIP and MEP were measured through capsule sensing pressure gauge (CSPG-V) manometer (Gauges Bourdon (I) pvt. Ltd, India: ISO 9001 certified). The participants were asked to exhale slowly and completely (to residual volume). Following this a nose clip was attached to prevent any breathing through the nose. The mouth piece of the manometer was put inside the mouth and participants were asked to seal lips firmly around the mouthpiece (to prevent air leak). They were asked to take a deep inspiration. Instruction given to the participants was "pull in hard, like you are trying to suck up a thick milk shake". The largest negative pressure sustained for 1 second was recorded and the maneuver was repeated 3 times. The average of three values was taken. The instrument has intra-rater reliability of 0.962 and inter-rater reliability 0.922.[20]

For measuring MEP the participants were asked to exhale forcefully and the instruction given was "blow air like you are trying to blow a candle". The largest positive pressure sustained for 1 second was recorded and the maneuver was repeated 3 times. The average of three values was taken.

Modified Borg scale (MBS)

Modified Borg dyspnea Scale was administered to score the difficulty in breathing. It was administered after the first and last session of training. The participants were asked to rate their difficulty of breathing in a scale of 0-10, where 0 indicates no difficulty in breathing at all and10 indicates maximal difficulty in breathing.[21]

Data analysis

Data were analyzed using SPSS version 21.0 for windows (SPSS Inc., Chicago, Illinois). Sample size was determined through power calculation based on previous studies for IMT training in spinal cord injury with an estimated effect size of 0.80 an overall sample of 16 participants (8 in each group) at 0.05 level of significance was estimated. However, 30 participants were recruited to allow 10% dropout. Mean change score were calculated as the difference between post and pre test scores and an independent t-test was used to test the difference in the changed scores between two groups.

Results

The demographic details of the participants are discussed in Table 1.

Within group analysis (Table 2).

Table 1 Details of participants.

Variables	Group 1 (n = 15) Mean ± SD	Group 2 (n = 12) Mean ± SD	P values
Age(in years)	29.0 ± 12.6	34.4 ± 13.0	0.94
Height(in meters)	1.6 ± 0.7	1.6 ± 0.1	0.10
Weight(in Kg)	63.6 ± 14.9	67.5 ± 9.0	0.67
BMI(m/kg)	22.5 ± 4.13	25.14 ± 2.74	0.27
TSI (in months)	8.20 ± 6.31	10.50 ± 8.94	0.28
AIS Grade	A-12	A-11	
	B-3	B-1	
Level of injury	T1-T4 -3	T1-T4 -4	
	T5-T7 -4	T5-T7 -2	
	T8-T12 -8	T8-T12 -6	
Sex	Males:13	Males:9	
	Females:2	Females:3	

[a]Continuous data presented as mean (standard deviation) and nominal data as proportions.
IMT Group = IMT group; Control Group = Control group; BMI, Body Mass Index; TSI, Time since injury; AIS, ASIA Impairment Scale; P values ≤ 0.05.

Group 1

Within group analysis showed significant improvements in respiratory muscle strength as assessed by scores of MIP (P = 0.001) and MEP (P = 0.001) in Group1. Similarly, there were improvements in MBS scores (P = 0.001). Statistically and clinically significant changes (P = 0.001) were seen in VO_2 max scores (13.7 ± 3.2 mlO_2/kg/min) of 12 MWAT when compared with the baseline values (6.8 ± 2.2 mlO_2/kg/min).The comparison of pre intervention (4.0 ± 1.9) and post intervention scores (7.8 ± 1.8) of MSFT showed significant differences (P = 0.001). Post intervention scores (187 ± 28.8) on 6 MPT were also higher as compared to baseline scores (136 ± 25.1) for Group 1 (P = 0.001).

Group 2

In this study, breathing exercise group also showed significant improvements on most of the outcomes variables. Aerobic capacity of SCI patients in the control group was better after training. The comparison of pre intervention (6.3 ± 3.0 mlO_2/kg/min) and post intervention scores (7.6 ± 2.5 mlO_2/kg/min) of VO_2 max measured using 12 MWAT for Group 2 showed significant difference (P = 0.001). Similar improvements were seen in post intervention scores of MSFT (5.2 ± 1.3) and 6 MPT (162.0 ± 10.3 meters) when compared with baseline scores. Significant changes were also seen in inspiratory pressure (P = 0.001) and MBS scores (P = 0.05) however expiratory pressure changes were non-significant (P = 0.17).

Between group analysis

Although there were significant changes in both the groups, results show that IMT group scored better than control group on 12 MWAT (95% CI, 3.9 to 9.2), MSFT (95% CI, 1.0 to 3.3), and 6MPT (95% CI, 15.9 to 44.4). The scores of MIP (95% CI, −30.2 to −12.1) and MEP (95% CI, 8.6 to 25.7) also show an improvement in IMT group after training as compared to control group. Likewise, there was significant effect on MBS score (95% CI, −3.2 to −0.6) in IMT group (Table 2; Fig. 2).

Discussion

Wheelchair exercise capacity is diminished in many persons with SCI and is related to a reduced level of functioning, decreased participation and quality of life.[22] The results of the present study show significant improvements in aerobic test performance scores after IMT training. Previous studies on the effects of IMT on respiratory function and exercise responses in SCI

Table 2 Comparison of mean change scores in IMT Group and Control Group.

	Group 1 (n = 15)		Group 2 (n = 12)				
Variables	Pre Mean(SD)	Post Mean(SD)	Pre Mean(SD)	Post Mean(SD)	Between Group Difference	95% CI	P values
MIP (cm H_2O)	-81.3 ± 23.5	-110 ± 14.6	-70.8 ± 27.7	-78.3 ± 27.5	-21.6	-30.2 – -12.1	0.001
MEP (cm H_2O)	41.3 ± 19.9	62.6 ± 20.5	45.0 ± 18.8	49.1 ± 17.2	17.1	8.6-25.7	0.001
MBS scores	4.1 ± 2.4	1.0 ± 1.2	2.7 ± 1.8	1.3 ± 0.9	-1.9	-3.2- -0.6	0.004
12MWAT(mlO_2/kg/min)	6.8 ± 2.2	13.7 ± 3.2	6.3 ± 3.0	7.6 ± 2.5	5.0	3.9-9.2	0.001
MSFT scores	4 ± 1.92	7.8 ± 1.8	3.5 ± 1.1	5.2 ± 1.3	2.2	01.0-3.3	0.001
6MPT (meters)	136 ± 25.16	187 ± 28.8	141.2 ± 19.7	162.0 ± 10.3	30.1	15.9-44.4	0.001

IMT Group = IMT group; Control Group = Control group; MIP, Maximum Inspiratory pressure expressed as centimeters of water (cm H_2O); MEP, Maximum Expiratory Pressure expressed as centimeters of water (cm H_2O); MBS, Modified Borg Scale;12MWAT, 12 minute wheelchair aerobic test; MSFT, Multi stage fitness test; 6MPT, 6 minute push test. CI, Confidence Interval; P values ≤ 0.05.

have reported the effects of resisted exercise muscle training in athletic populations. To our knowledge, no study has explored the effect on non-athletic population. The participants in our study were not engaged in any form of competitive or recreational sports. Deterioration in aerobic performance post SCI is related to reduced inspiratory muscle strength.[3] Pereira[23] observed that 36% and 50% of aerobic performance tests were influenced by inspiratory muscle strength in without trunk control group and with trunk control group respectively in wheelchair basketball players. It is believed that respiratory muscle fatigue alters exercise performance via metaboreflex[13] in which there is accumulation of metabolites such as lactic acid in the respiratory muscles. This in turn, triggers the sympathetic outflow from the brain causing vasoconstriction in the exercising limb leading to increased muscle fatigue and early exercise termination.

In our study, participants in IMT group performed significantly better than control group for 12MWAT (IMT group 13.7 ± 3.2 ml/kg/min versus 7.6 ± 2.5 ml/kg/min control group), MSFT (IMT group 7.8 ± 1.8 versus 5.2 ± 1.3 control group) and 6MPT (IMT group 187 ± 28.8 meters versus 162.0 ± 10.3 meters control group) (Table 2). The results of this study are in agreement with those described by West *et al.*[3] who found that the group which received IMT showed significant increase in diaphragm thickness (P = 0.001) along with an increase in peak work rate (P = 0.081) and peak oxygen uptake (P = 0.077). Previous studies done on healthy participants have shown that strengthening of respiratory muscles enhances exercise performance. In one study use of IMT resulted in improvement in running performance in a group of sixty athletes.[24] In a study conducted by Enright *et al.* it has been seen that 8 weeks of IMT training resulted in improvement in exercise capacity

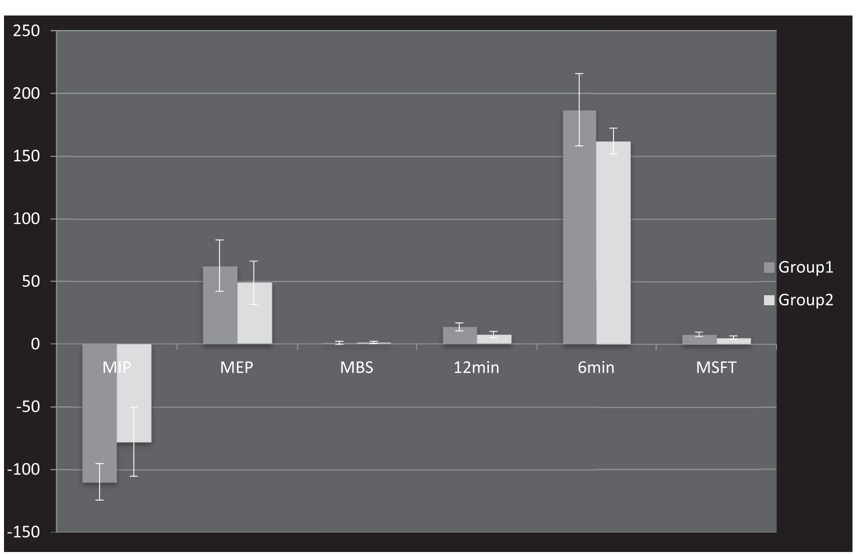

Figure 2 Comparison between post intervention scores of group 1 and group 2.

in healthy adults.[9] Another study conducted by Kim *et al*. on 20 stroke patients respiratory muscle training using IMT resulted in significant improvements in FVC, FEV1, PEF, six minute walk test and Modified Borg dyspnea scores.[11] Similar results were established by Ujil *et al*. who performed target flow endurance training for respiratory muscles in tetraplegics and found that VO_2 peak increased from 0.87 to 0.98 l/min after 6 weeks of training.[12]

Weakness of abdominal muscles in SCI reduces the efficiency of wheelchair propulsion as these muscles are involved in trunk control.[25,26] In a previous study,[27] MEP scores were positively correlated with distance covered in aerobic performance test suggesting that better MEP scores in IMT group (62.6 ± 20.5 cm H_2O) as compared to control group (49.1 ± 17.2 cm H_2O) could also be a contributing factor.

Contrary to our findings studies done by Litchke *et al*.[27] Mueller *et al*.[28] and Tolfrey *et al*.[29] found that IMT had no effects on aerobic performance in SCI. One explanation for such contradiction could be that in these studies athletes with high fitness level were recruited and also large inter individual differences were present within the study population.

There was also an improvement in dyspnea scores in IMT group. Study by Liaw[15] suggests that with increased oxygen demand during physically strenuous activities, the effort of breathing is increased. Studies have shown that IMT results in improvement of respiratory muscle strength and fatigue tolerance.[7]

The control group showed significant improvements in aerobic capacity. Previous studies have shown that deep breathing improves chest wall motion and ventilation. This then contributes to low energy cost of breathing thus improving exercise performance and reducing dyspnea.[16]

The study however had certain limitations. First, field tests were used to determine VO_2 max in these participants owing to the lack of sophisticated equipment. Future studies with cardiopulmonary testing with gas analysis could predict more accurate values of VO_2 max. Secondly, pre fitness level of paraplegics was not assessed. Thirdly, carry-over effects of IMT were not studied. We were not able to establish the long term changes in SCI which may have occurred due to increased aerobic capacity in these individuals. Future studies could be undertaken to see the effect of improved aerobic capacity on overall wellbeing and quality of life in these subjects.

The clinical implications of this study are IMT improves performance in aerobic performance tests in paraplegics and less fit individuals seem to benefit more from IMT than highly trained athletes. Hence, this training could benefit paraplegics in early phase of rehabilitation and can be given to improve their aerobic performance.

Conclusion

In this study, although both inspiratory muscle training and deep breathing exercises showed significant benefits in paraplegics however, IMT was more effective in improving aerobic capacity, respiratory muscle strength and rate of perceived exertion than deep breathing exercises in these patients.

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Conflict of Interest The authors report no conflicts of interest.

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